A 360-degree overview of body composition in healthy people: relationships between anthropometry, ultrasonography and dual-energy x-ray absorptiometry

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Aims and objectives

The study of body composition (BC) is a field devoted to the quantification of the amount and distribution of elements that compose the body at different levels [1-2].

The human body can be specifically organized into five levels of increasing complexity: atomic, molecular, cellular, organ-tissue, whole-body [3]. Numerous techniques are able to perform BC assessment at each level [4].

At the molecular level of human BC, a reference standard technique is represented by dual-energy x-ray absorptiometry (DXA). DXA measurements are based on a 3-compartment model that can be simplified in fat mass (FM), non-bone lean mass (LM) and bone mineral content (BMC). This technique is able to assess FM, LM, BMC regionally and whole-body as well as it can measure whole-body and regional bone mineral density (BMD) [5].

Furthermore, a new software has recently been validated to separately quantify the visceral compartment of android fat by DXA with excellent results in comparison with computed tomography [6].

DXA is accurate, reproducible, fast, relatively inexpensive, and exposes patients to very low radiation dose. All these advantages make this densitometric method ideal for clinical use and longitudinal studies, in both adults and children [7].

At the whole-body level, among anthropometric measurements waist circumference (WC), hip circumference and other calliper measurements are commonly used in daily clinical practice. Moreover, waist-to-hip ratio (WHR) and body mass index (BMI) represent fundamental and widespread indexes. Anthropometric data are easy to be obtained and cost-effective but suffer from low accuracy and reproducibility [8].

Ultrasonography (US) is a technique with a potential role in studying BC between whole-body and organ-tissue levels. This technique allows to directly measure visceral (VAT) and subcutaneous (SAT) thicknesses at different axial sections of the abdomen, overcoming some limits of anthropometry and conventional DXA machines. US is accurate, reproducible, easy and fast in the analysis of abdominal adiposity [9-11].

Very few studies considered an integration of all the main techniques involved in the clinical assessment of BC, such as anthropometry, US and DXA [12].
The aim of the study was to test the association of anthropometry, US and DXA for the assessment of BC in clinical practice and to explore how anthropometry and US might predict and correlate with fundamental biomarkers of BC by DXA.
Methods and materials

The study was carried out in Italian blood donor volunteers belonging to in 5 different age groups (from 18 to 70 years old 25 males and 25 females per group (total: 250 subjects; 125 males, 125 females). A complete history and routine blood analyses were performed to confirm healthy status.

All subjects were submitted to whole-body DXA (tricompartimental analysis, regional and total-body), ultrasonography (abdominal adiposity evaluation) and anthropometric measurements. DXA was used as gold standard and its biomarkers were taken as reference for (a) fat/lean mass balance, (b) central/peripheral fat distribution, (c) central fat or visceral fat, and (d) subcutaneous fat.

Anthropometry

BMI was calculated as weight/height$^2$ (Kg/m$^2$). WC was measured at the midpoint between the lowest rib bone on the sides and the iliac crest; hip circumference (HC) was measured at the level of the femoral great trochanter (Fig. 1 on page 7a); moreover the WHR was calculated (WC/HC). All circumferences were measured in centimetres using a flexible plastic measuring tape to the nearest 0.1 cm, with the subject wearing only underwear and standing, at the end of a normal expiration.

Ultrasonography

In addition to anthropometric measurements we examined the distribution pattern of abdominal fat by measuring several abdominal fat thicknesses and parameters (Fig. 1 on page 7b). All measurements were acquired with subjects in a supine position with arms at sides, at the end of a normal expiration.

Maximum preperitoneal fat thickness (MaxPFT) was determined below the xiphoid process in the epigastric region, on the xiphoumbilical line, as the major distance between the anterior surface of the peritoneum covering the liver (left lobe) and the posterior surface of the linea alba. Minimum subcutaneous fat thickness (MinSFT) was measured at the same anatomic region. Maximum subcutaneous fat thickness was assessed at two different sites on the linea alba, 2 cm over and 2 cm below the umbilicus (MaxSFT$^{upper}$ and MaxSFT$^{lower}$, respectively). MinSFT, MaxSFT$^{upper}$ and MaxSFT$^{lower}$ were defined as the distance between the anterior surface of the linea alba and the fat-skin barrier.

Intrabdominal fat thickness (IFT) was measured as the distance between the anterior wall of the aorta and the posterior surface of the linea alba, 2 cm below the umbilicus (as for MaxSFT$^{upper}$).
MaxPFT, MinSFT, MaxSFT\textsubscript{upper} and MaxSFT\textsubscript{lower} were measured using a linear probe (7.5 MHz) kept perpendicular to the skin and hand pressure on the abdomen as light as possible, to avoid compression of fat layers; IFT was assessed using a convex probe (3.5 MHz) [9].

The \textit{aorto-mesenteric thickness} was assessed using a convex probe, 2 cm below the aorto-mesenteric bifurcation as the distance between the anterior margin of the aorta and the posterior profile of the superior mesenteric artery [13].

Several adiposity indexes were also calculated: a) \textit{preperitoneal circumference}, as the difference between waist circumference and MaxSFT\textsubscript{upper} multiplied by 2\# [9]; b) \textit{wall fat index}, as the ratio between MaxPFT and MinSFT [9]; c) \textit{medium abdominal fat index}, as the ratio between IFT and MaxSFT\textsubscript{upper}.

\textbf{Dual-energy x-ray absorptiometry}

A whole-body DXA scan was performed to measure total and regional body composition using a new fan-beam densitometer (Lunar iDXA, enCORE\textsuperscript{TM} 2011 software version 13.6). The subjects were placed in a supine position with arms at sides slightly separated from the trunk and correctly centered on the scanning field. Region of interests (ROIs) were defined by the analytical program including six different corporeal districts: \textit{total body, trunk, upper limbs, lower limbs, android region} (a portion of the abdomen included between the line joining the two superior iliac crests and extended cranially up to the 20% of the distance between this line and the chin) and \textit{gynoid region} (a portion of legs from the femoral great trochanter, directed caudally up to a distance double of the android region). For each region, DXA scanned the weight (in g) of total mass, FM, LM, and BMC.

Visceral fat analysis was performed by CoreScan, a new software option for the assessment of visceral fat (mass and volume) in the android region [6]. The measurement of SAT thickness at both sides of the android region allowed the software to map the total SAT compartment. The amount of android VAT was derived by subtracting SAT from total android FM (Fig. 1 on page 7c).

\textbf{Statistical methods}

The relationship between parameters derived from the different techniques was investigated by using DXA as reference technique. In particular, total body FM/LM (a), android/gynoid FM (b), android FM/LM (c), VAT (d), VAT/SAT (e), and SAT (f) were considered as the pivotal markers of body composition, in terms of general mass balance (a), central/peripheral distribution of FM (b), central or VAT compartment (c, d, and e for fat abdominal distribution), and SAT depot (f), respectively.
Pearson's test was used to evaluate the correlations between the BC parameters provided by DXA and the anthropometric and ultrasound values. The analysis was performed separately in males and females. Since three methods (DXA, anthropometry and US) were simultaneously applied to the study of body composition in the whole population, the statistical significance was set according to Duncan's multiple range as $p < 0.025$. Statview statistical package (version 5.0.1 for Windows; SAS Inc., Chicago, IL, USA) was used for the analysis.
**Fig. 1:** (a) The two body sites for anthropometric measurements: the upper broken circle represents the waist circumference and the lower one the hip circumference. (b) The abdominal section shows three axial levels of US assessment: maximum preperitoneal fat thickness (1); minimum subcutaneous fat thickness (2); intra-abdominal fat thickness (3); maximum subcutaneous fat thickness (4) maximum subcutaneous fat thickness 2 cm below the umbilicus (5). (c) Colored map of whole-body scan by DXA (yellow, high fat percentage # conventionally > 60%; orange, medium fat percentage # between 25 and 60%; red, low fat percentage # < 25%) highlights the regional assessment of body composition (trunk # T, upper limbs # U, lower limbs # L, android # A and gynoid # G). In the lower right corner, the box magnifies the lateral android region with the subcutaneous fat layer pointed out (body section designed by Emiliano Mariani; Medical Illustrator, Faenza, Italy).
Results

The anthropometric, US and DXA features of the population are shown in Table 1 on page 10. Table 2 on page 10 reports the results of Pearson's analysis, considering DXA parameters as reference.

Composite markers representative of central and abdominal visceral fat compartment were significantly correlated with waist circumference, waist-to-hip ratio, and intrabdominal fat thickness by ultrasound, in both males and females (p<0.025). As expected, subcutaneous depots were significantly correlated with maximum subcutaneous fat thickness measured by ultrasonography (p<0.025).

The US indexes of VAT compartment (wall fat index and medium abdominal fat index) did not significantly correlate with any DXA parameter under investigation.
Table 1: Descriptive statistics for densitometric, anthropometric and ultrasonographic parameters (mean ± standard deviation. BMI, body mass index; WC, waist circumference; HP, hip circumference; WHR, waist-to-hip ratio; MinSFT, minimum subcutaneous fat thickness; MaxPFT, maximum preperitoneal fat thickness; MaxSFTUpper, maximum subcutaneous fat thickness 2 cm over the umbilicus; MaxSFTLower, maximum subcutaneous fat thickness 2 cm underneath the umbilicus; IFT, intrabdominal fat thickness; PC, preperitoneal circumference; AOMT, aortomesenteric thickness; MAFI, medium abdominal fat index; WFI, wall fat index; TFM, total fat mass; TLM, total non-bone lean mass; AFM, android fat mass; ALM, android non-bone lean mass; A/G FM, android/gynoid fat mass; VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue.

| Table 2: Pearson’s coefficients for anthropometric, ultrasonographic and reference standard densitometric parameters of body composition analyzed separately in males and females. BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio; MinSFT, minimum subcutaneous fat thickness; MaxPFT, maximum preperitoneal fat thickness; MinSFTUpper, maximum subcutaneous fat thickness 2 cm over the umbilicus; MaxSFTLower, maximum subcutaneous fat thickness 2 cm underneath the umbilicus; IFT, intrabdominal fat thickness; PC, preperitoneal circumference; AOMT, aortomesenteric thickness; MAFI, medium abdominal fat index; WFI, wall fat index; TFM, total fat mass; TLM, total non-bone lean mass; AFM, android fat mass; ALM, android non-bone lean mass; A/G FM, android/gynoid fat mass; VAT, visceral adipose tissue; SAT, subcutaneous adipose tissue. |
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Conclusion

Both anthropometry and ultrasonography give a reliable estimate of visceral adipose tissue in a non-obese population, compared to DXA, whereas their prediction of subcutaneous adiposity is weak. Physicians should be aware of the limits of these techniques for the assessment in body composition.
Personal information

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References


